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Indian Standard

SPECIFICATION FOR VARIABLE CAPACITORS

PART I TESTS AND GENERAL REQUIREMENTS

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SPECIFICATION FOR VARIABLE CAPACITORS

PART I TESTS AND GENERAL REQUIREMENTS

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Indian Standard

SPECIFICATION FOR VARIABLE CAPACITORS

PART I TESTS AND GENERAL REQUIREMENTS

0. FOREWORD

0.1 This Indian Standard (Part I) was adopted by the Indian Standards Institution on 16 July 1975, after the draft finalized by the Capacitors and Resistors for Electronic Equipment Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 The object of this standard is to establish uniform requirements for judging the mechanical, electrical and environmental properties of variable capacitors, the capacitance of which is likely to be frequently varied throughout its useful life.

0.3 This standard covers general requirements and test methods for all types of variable capacitors intended for use in electronic equipment. The specific tests and appropriate requirements of particular types of such capacitors will be covered in individual specifications. All tests covered in this standard may not be applicable to each and every type of capacitor.

0.4 The variable capacitors covered by this standard are divided according to their type (function), dielectric, style and application. The specific tests and requirements which are applicable to particular type of variable capacitors will be covered by relevant individual specification.

0.5 Necessary references have been made in this standard to IS : 589-1961* in which details of the various climatic and mechanical durability tests have been covered. Only the applicable degrees of severity, special conditions and performance figures in some cases have been included in this standard.

0.6 This standard is one of a series of Indian Standards relating to capacitors used in electronic and telecommunication equipment. A list of standards published so far in the series is given on fourth cover page.

0.7 This standard has been largely based on IEC Pub 418-1(1974) 'Variable capacitors : Part I Terms and methods of test' issued by the International Electrotechnical Commission.

0.8 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing

*Basic climatic and mechanical durability tests for electronic components (*revised*).

the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard (Part I) covers tests and general requirements relating to variable capacitors used in electronic and telecommunication equipment.

1.1.1 The general requirements and tests described in this standard are applicable to each section of multi-section capacitors, unless otherwise specified in the relevant individual specification.

1.2 This does not include electronically variable capacitors such as semiconductor variable capacitors.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

2.1 Variable Capacitor — A capacitor which is designed to enable the capacitance to be varied continuously over its complete range.

2.1.1 *Variable Capacitor, Type A (Tuner Capacitor)* — A capacitor intended to be operated frequently throughout its life. When used for tuning purposes this capacitor may be provided with a control spindle to which a knob or drive may be fitted.

2.1.2 *Variable Capacitor, Type B (Trimmer Capacitor)* — A capacitor used for trimming or for other similar purposes where considerably fewer operations are required than for Type A.

2.1.3 *Variable Capacitor, Type C (Preset Capacitor)* — A capacitor used specifically as a preset capacitor where a comparatively small number of movements are required during its life.

2.2 Differential Capacitor — Two isolated stators which are operated with one rotor arranged so that as the capacitance between the rotor and one stator increases the capacitance between the rotor and the other stator decreases but the sum of the two capacitance value remains constant for all settings.

2.3 Split Stator Capacitor — Two isolated stators which function in series with a common rotor.

2.4 Section — A stator and its corresponding rotor.

*Rules for rounding off numerical values (*revised*).

2.5 Multi-Section Capacitor — A multi-section capacitor is one which has several sections, the capacitance values of which are varied simultaneously by a common actuating device.

2.6 Reference Section — That section to which other sections can be matched.

2.7 Matching Section — A section matched to a reference section.

2.8 Type (Function) — A type comprises products having similar design features manufactured by the same technique and falling within the manufacturers usual range of ratings of those products and being normally covered by a single detail specification.

NOTE — The type (function) of variable capacitor is determined by the function and is governed by the ability of the capacitor to withstand various severities of mechanical endurance specified in this standard.

2.9 Style — The method for varying the capacitance.

NOTE — A style comprises products of the same functional types having similar means of varying the capacitance.

2.9.1 *Style 1 (Concentric)* — An air dielectric variable capacitor where the capacitance may be varied by the axial movement of a rotor in a stator.

2.9.2 *Style 2 (Vane)* — A variable capacitor where the capacitance may be varied by rotating the rotor vane(s) between the stator vane(s).

NOTE — The style 2 is applicable to air dielectric and solid dielectric.

2.9.3 *Style 3 (Tubular)* — A solid dielectric variable capacitor where the capacitance may be varied by the axial movement of an electrode within a tube.

2.9.4 *Style 4 (Compression)* — A solid dielectric variable capacitor where the capacitance may be varied by compressing a stack of electrode and dielectric layers.

2.9.5 *Style 5 (Disc)* — A solid dielectric variable capacitor where the capacitance may be varied by rotating a metal or metallized disc.

2.10 Grade — A description denoting a specific application such as domestic, professional and long life.

2.11 Maximum Capacitance — The maximum value which may be obtained with the actuating device adjusted in the manner prescribed in the relevant specification.

2.12 Minimum Capacitance — The minimum value which may be obtained with the actuating device adjusted in the manner prescribed in the relevant specification.

NOTE — This is also known as residual capacitance.

2.13 Capacitance Swing — The difference between maximum and minimum capacitance.

2.14 Capacitance Law — The relationship between capacitance and the position of the actuating device.

2.15 Total Angle of Rotation — The angle (or number of turns) through which the rotor moves between the end stops. If there are no end stops then the total angle of rotation is the effective angle of rotation (*see* **2.16**).

NOTE — The angle of rotation is expressed either in terms of degrees or in terms of number of turns.

2.16 Effective Angle of Rotation — The angle (or number of turns) through which the rotor moves between the positions of maximum and minimum capacitance.

2.17 Nominal Angle of Rotation — The angle of the rotor for determining the measuring points when capacitance law measurements are made.

2.18 Backlash — The difference in capacitance (expressed as a ratio) obtained at prescribed measuring angle when the actuating device is moved to approach this measuring angle from a clockwise and then from an anti-clockwise direction.

2.19 Apparent Power — The maximum VA rating at which the capacitor may be used in relation to temperature rise, in terms of frequency, current and voltage.

2.20 Upper Category Temperature — The highest ambient temperature at which the capacitor is designed to operate continuously.

2.21 Lower Category Temperature — The lowest ambient temperature at which the capacitor is designed to operate continuously.

2.22 Category Temperature Range — The range of ambient temperatures for which the capacitor is designed for continuous operation.

2.23 Capacitance Drift After Adjustment — The change in capacitance expressed as a ratio obtained in a stated time after the rotor has been rotated with a specified speed to a stated capacitance.

2.24 Nominal Capacitance — The capacitance values which are indicated upon the capacitors or the package.

2.25 Rotor Contact Resistance — The resistance between the rotor contact terminal and the rotor shaft.

2.26 Rated Voltage — The maximum peak voltage which may be applied continuously to the terminals of a capacitor at any temperature in the category temperature range.

2.27 Type Tests — Tests carried out to prove conformity with the requirements of this standard. These tests are intended to prove the general quality and design of a given type of capacitor.

2.28 Routine Tests — Tests carried out on each capacitor to check the requirements which are likely to vary during production.

2.29 Acceptance Tests — Tests carried out on samples which have passed the routine tests selected from a lot for the purpose of acceptance of the lot.

2.29.1 *Lot* — All capacitors of the same type, category and ratings manufactured by the same factory during the same period.

3. DESCRIPTIVE CODE FOR VARIABLE CAPACITORS

3.1 The description of the type (function), dielectric, style and application (grade) of a variable capacitor may be in the form of a four character code as follows:

a) Type (function)	A = Tuner capacitor B = Trimmer capacitor C = Preset capacitor
b) Dielectric	1 = Air 2 = Solid
c) Style	1 = Concentric 2 = Vane 3 = Tubular 4 = Compression 5 = Disc
d) Application (grade)	1 = Professional 2 = Domestic

Example — For a preset capacitor, solid dielectric, tubular style, for professional application, the descriptive code is C231.

4. CLIMATIC CATEGORIES

4.1 The variable capacitors shall belong to the categories as specified in the relevant specification depending on the severities of the climatic tests which they can withstand.

5. CONSTRUCTION AND WORKMANSHIP

5.1 The capacitors shall incorporate suitable arrangements for being fixed to the chassis of the equipment.

5.2 Workmanship — The capacitors shall be manufactured in a thoroughly workmanlike manner and in accordance with the current engineering practice.

6. RATINGS

6.1 Nominal Capacitance — This shall be specified in the relevant individual specification and shall comprise one or more of the following:

a) Capacitance swing (nominal),

b) Maximum capacitance (nominal), and

c) Minimum capacitance (nominal).

6.2 Rated Voltage — The rated voltages shall be selected from the R5 series (*see* IS : 1076-1967*); where intermediate values are required, these shall be chosen from the R10 series.

6.3 Capacitance Law — Under consideration.

7. MARKING

7.1 Marking — The following particulars shall be marked on the container or packing of the capacitor; wherever practicable, these shall also be marked clearly and indelibly on each capacitor:

a) Capacitance swing;

b) Minimum capacitance;

c) Manufacturer's name/or trade-mark;

d) Descriptive code;

e) Manufacturer's type designation, if any;

f) Date of manufacture (may be in code); and

g) Any other marking agreed between the purchaser and the manufacturer.

7.1.1 The capacitor may also be marked with the ISI Certification Mark.

NOTE — The use of the ISI Certification Mark is governed by the provisions of the Indian Standards Institution (Certification Marks) Act and the Rules and Regulations made thereunder. The ISI Mark on products covered by an Indian Standard conveys the assurance that they have been produced to comply with the requirements of that standard, under a well-defined system of inspection, testing and quality control which is devised and supervised by ISI and operated by the producer. ISI marked products are also continuously checked by ISI for conformity to that standard as a further safeguard. Details of conditions, under which a licence for the use of the ISI Certification Mark may be granted to manufacturers or processors, may be obtained from the Indian Standards Institution.

8. GENERAL CONDITIONS FOR TESTS

8.1 Selection of Samples — The samples for tests shall be so selected as to be representative of the range of capacitance values and voltage ratings of the type under consideration.

*Preferred numbers (*first revision*).

8.1.1 *Samples* — The number of samples required shall be prescribed in the relevant specification. Capacitors which have been subjected to the type tests shall not be used in equipment or returned to bulk supply.

8.2 Atmospheric Conditions for Tests — Unless otherwise specified, all the tests included in this standard shall be carried out under the standard atmospheric conditions for tests as prescribed in IS : 589-1961*. During these measurements, the test samples shall be protected from draughts and direct sun-rays. Where measurements are required during conditioning periods, the same requirement shall apply unless otherwise specified.

8.3 Pre-conditioning — Before the measurements are made, the capacitors shall be stored at the measuring temperature and relative humidity for a time sufficient to allow the entire capacitor to reach these conditions. The recovery period called for after climatic conditioning is normally adequate for this purpose.

8.4 Correction to be Applied — Where measurements are made at a temperature other than the reference temperature, the results shall, wherever necessary, be corrected to the reference temperature. The ambient temperature during the measurement shall be stated in the test report. The correction factor shall be specified in the relevant individual specification.

8.5 Drying — Where drying is called for in this standard, it shall be carried out in accordance with **4.5** of IS : 589-1961*.

8.6 Mounting — Care shall be taken in the relevant individual specification to fully describe the mounting arrangements since these may affect measurements of minimum capacitance and temperature coefficient. The relevant specification shall prescribe which of the following methods of mounting shall be used:

a) *Method A* — The capacitor shall be rigidly mounted by the means provided, without causing abnormal stressing

b) *Method B* — The capacitor shall be rigidly mounted by its normal means on a flat machined metal plate, approximately 3 mm thick and at least 25 mm larger than the linear dimensions of the mounting face of the capacitor without causing abnormal stressing

c) *Method C* — The capacitor shall be rigidly mounted by its normal means on a metal plate, larger than the projection of the capacitor, without causing abnormal stressing

d) *Method D* — Any other method as described in the relevant specification

*Basic climatic and mechanical durability tests for electronic components (*revised*).

8.7 Test Conditions

8.7.1 The method specified initially for any test or measurement shall, unless otherwise specified, be used for all subsequent application of that test or measurement.

8.7.2 Where a test requires an application of torque the method used shall be such as to ensure an accuracy of ± 10 percent.

9. CLASSIFICATION OF TESTS

9.1 Type Tests — The schedule for type tests shall be prescribed in the relevant specification.

9.1.1 *Type Approval Procedure* — The procedure for type approval shall be as recommended in IS : 2612-1965*.

9.1.2 *Number of Samples and Sequence of Type Tests* — The minimum number of samples for type tests and the sequence shall be stated in the relevant specification.

NOTE — Capacitors which have been subjected to type tests shall not be used in equipment or returned to bulk supply.

9.2 Acceptance Tests — The acceptance tests shall be as specified in the relevant specification.

9.2.1 *Sampling Procedure* — The sampling procedure shall be as specified in the relevant specification in accordance with IS : 2612-1965*.

9.3 Routine Tests — The routine tests shall be as stated in the relevant specification.

10. GENERAL TESTS

10.1 Visual Examination — The condition, workmanship, marking and finish shall be satisfactory as determined by visual examination.

10.2 Dimensions — The dimensions shall be checked for conformity with those specified in the relevant individual specifications or by the manufacturer.

10.3 Effective Angle of Rotation — The effective angle of rotation shall be checked for conformity with that specified in the relevant individual specifications or by the manufacturer.

*Recommendation for type approval and sampling procedure for electronic components.

11. ELECTRICAL TESTS

11.1 Capacitance — For measurements of capacitance the measuring method shall be such that the error does not exceed:

a) 10 percent of the rated capacitance or tolerance for absolute capacitance measurements.
b) 10 percent of the specified maximum capacitance change for measurements of capacitance change.

11.1.1 *Capacitance Measurement* — The capacitor shall be mounted as specified in the relevant specification using one of the methods prescribed in **8.6**. The low potential side of the test equipment shall be connected to either the metal plate or the rotor connections, as applicable.

11.1.1.1 The capacitance shall be measured as specified in the relevant specification. Whatever the measuring frequency the capacitance value shall be correlated to primary standards of capacitance calibrated at 1 kHz.

11.1.1.2 Tuner capacitors may be fitted with trimmers. When this is so, the trimmer should be set at minimum capacitance for all tests. The trimmer should be separately tested to the relevant specification.

11.1.2 *Maximum Capacitance* — When measured as specified in **11.1.1** with the actuating device adjusted in the manner prescribed in the relevant specification the capacitance shall be as specified in the relevant specification.

11.1.2.1 The relevant specification shall specify:

a) the maximum capacitance and the limits, and
b) the position of the actuating device or how this position is obtained.

11.1.3 *Minimum Capacitance* — When measured as specified in **11.1.1** with the actuating device adjusted in the manner prescribed in the relevant specification the capacitance shall be as specified in the relevant specification.

11.1.3.1 The relevant specification shall specify:

a) the minimum capacitance and the limits, and
b) the position of the actuating device or how this position is obtained.

11.1.4 *Capacitance Swing* — The calculated capacitance swing shall be within the limits specified in the relevant specification.

11.1.5 *Capacitance Law*

11.1.5.1 When measured as specified in **11.1.1** the capacitance values of the reference section at the different measuring angles specified in the

relevant specification shall be within the limits specified in the relevant specification. For multi-section capacitors, the reference section shall be stated in the relevant specification.

NOTE — This test is generally applicable to variable capacitor, type A.

11.1.5.2 The points at which measurements are made shall be selected from the following:

0—5*—10—95—100 percent (at 5 percent intervals) of the nominal angle of rotation (which is normally 180°) specified in the relevant specification.

The maximum capacitance position as defined in **2.11** shall be considered to be at 100 percent rotation and shall be the reference point for the nominal angle of rotation.

The capacitance value at the first of the selected measuring positions (normally 5 percent rotation or at the end of the percentage of rotation specified in the relevant specification) shall be the zero reference capacitance for the purposes of this test (*see* Fig. 1).

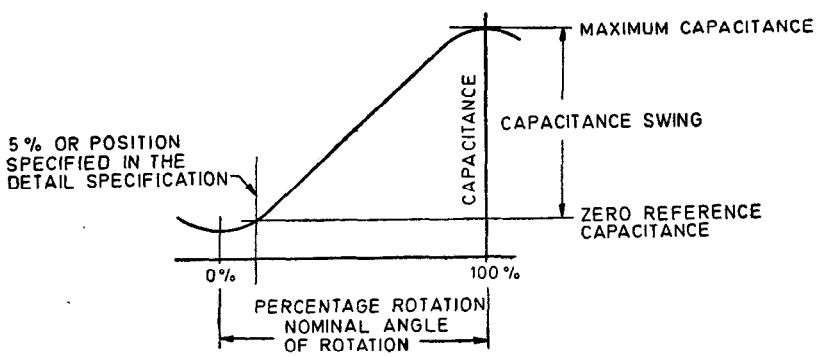


FIG. 1 ILLUSTRATION OF CAPACITANCE MEASURING POSITIONS

For a capacitor which has an increase of capacitance in both directions of rotation, when measured, the direction in which the actuating device is turned for increasing the capacitance shall be stated in the relevant specification.

The relevant specification shall state the differences in capacitance from the zero reference capacitance at each of the selected measuring positions.

*Either at 5 percent or at the percentage of rotation specified in the relevant specification.

The change of capacitance shall never change sign as the actuating device is operated in one direction between the minimum and maximum capacitance positions.

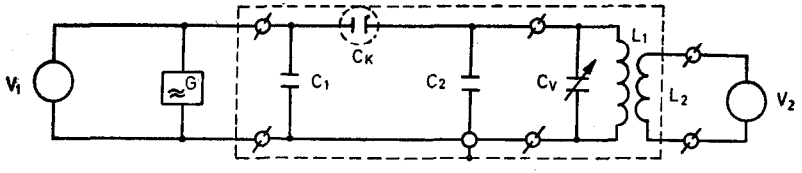
11.1.5.3 The matching between any other section and the reference section of multi-section capacitors (not differential types) shall be within the limits specified in the relevant specification. For this measurement the circuits shall be balanced at 5 percent of the nominal angle of rotation or at the position specified in the relevant specification.

11.1.6 *Coupling Capacitance* — Where coupling between sections of a multi-section capacitor is important the limits of coupling shall be specified in the relevant specification.

11.1.6.1 The capacitor shall be mounted as specified in the relevant specification, using one of the methods specified in **8.6** and shall be set at minimum capacitance position.

11.1.6.2 When measuring the coupling capacitance between two sections, any other section shall be connected to the low potential side of the test equipment.

11.1.6.3 The circuit for the measurement shall be as given in Fig. 2.



V_1 and V_2 = h.f. voltmeters
G = h.f. generator
L_1 = coil
L_2 = coupling coil [coupling $\frac{e_1}{e_2} = 40$ (where e_1 and e_2 are primary and secondary voltages respectively)]
C_1 and C_2 = sections of the capacitor to be measured
C_k = coupling capacitance
C_v = trimmer capacitor

FIG. 2 MEASURING CIRCUIT FOR COUPLING CAPACITANCE

11.1.6.4 The coupling capacitance is given by the formula:

$$C_k = \frac{C_{tot}}{Q} \cdot \frac{40 V_2}{V_1 - \frac{40 V_2}{Q}}$$

where

C_{tot} = the total capacitance which is required in parallel to L_1 for a frequency of 250 kHz, and

Q = the dissipation factor of L_1 at 250 kHz, provided that the C_{tot} dissipation factor exceeds considerably the dissipation factor of L_1 at the same frequency.

11.1.6.5 The coupling capacitance shall fulfil the limits specified in the relevant specification.

11.1.6.6 The relevant specification shall specify:

a) the sections between which the coupling capacitance shall be measured, and

b) the limits of the coupling capacitance.

11.2 Capacitance Drift After Adjustment

11.2.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

11.2.2 The rotor shall be set at a position representing approximately 90 percent of the nominal maximum capacitance.

11.2.3 The actuating device shall then be operated with a smooth continuous movement at a speed of approximately 30 degrees per second to a near minimum capacitance position and returned to approximately the original position.

11.2.4 Five seconds after this position has been reached the capacitance (C_a) shall be measured. After an interval of 2 minutes the capacitance shall be measured again (C_b).

11.2.5 The capacitance drift between 5 seconds and 2 minutes measuring points shall be calculated from the following formula:

$$N = \frac{(C_a - C_b)}{C_a} \times 10^6$$

where N = capacitance drift.

11.2.6 The capacitance drift determined shall be within the limits specified in the relevant specification.

The relevant specification shall specify:

a) the method of mounting, and

b) the limits of capacitance drift.

11.3 Tangent of Loss Angle

11.3.1 The capacitors shall be mounted as prescribed in the relevant specification using one of the methods specified in **8.6**.

11.3.2 The tangent of loss angle shall be determined at a frequency as prescribed in the relevant specification with the rotor set at the capacitance

value(s) specified in the relevant specification. The accuracy of measurement should be within 10 percent of the specified value of tangent of loss angle.

11.3.3 The value(s) of the tangent of loss angle shall be within the limits specified in the relevant specification.

11.3.4 The relevant specification shall specify:

a) the method of mounting,
b) the measurement frequency,
c) capacitance value(s), and
d) the maximum value(s) of the tangent of loss angle.

11.4 Voltage Proof

11.4.1 The capacitors shall be mounted as described in the relevant specification using one of the methods specified in **8.6**.

11.4.2 There shall be no breakdown when the voltage described in the relevant specification is applied between the rotor and stator of each section. If an alternating supply is used the test shall be carried out at normal supply frequency. The test voltage shall be applied for a period of 1 minute $\pm$ 5 seconds while the rotor is moved through the effective angle of rotation.

NOTE — For air dielectric capacitors preliminary sparking due to the accumulation of dust may be ignored.

11.4.3 For the purpose of a measurement during or at the end of other tests the test voltage shall be applied for a period of 2 seconds with the capacitor set at the maximum capacitance position or as otherwise specified for the relevant test.

11.4.4 When the capacitor has an insulated mounting device the test voltage shall also be applied between the following points as specified in the relevant specification:

a) The rotor and the mounting plate,
b) The stator and the mounting plate, and
c) Rotor and stator (if applicable).

11.4.5 The relevant specification shall specify:

a) the method of mounting,
b) the test voltage, and
c) points of application of the test voltage (if other than above).

11.5 Insulation Resistance

11.5.1 The capacitors shall be mounted as described in the relevant specification using one of the methods specified in **8.6**.

11.5.2 The insulation resistance shall be measured using the following test voltages as appropriate:

Rated Voltage, U_R	*Test Voltage*
$U_R \geqslant 500$	500 ± 50
$100 < U_R < 500$	100 ± 15
$U_R \leqslant 100$	U_R

11.5.3 The test voltage shall be applied for 1 minute $\pm$ 5 seconds between parts which are insulated from each other. Throughout the test the rotor shall be set at the positions specified in the relevant specification.

11.5.4 The insulation resistance shall be not less than the value specified in the relevant specification.

11.5.5 The relevant specification shall specify:

a) the method of mounting,

b) points of application of the voltage,

c) position of the rotor, and

d) the minimum value of the insulation resistance.

11.6 Rotor Contact Resistance

11.6.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods of **8.6**.

11.6.2 The rotor contact resistance shall be measured between the rotor contact connection and the rotor shaft by passing a current through the contact causing a potential drop not exceeding 20mV dc. The current shall not exceed 1A dc or the value specified in the relevant specification. The measuring apparatus shall be such as to ensure an accuracy of $\pm$10 percent. The rotor contact resistance shall be measured at any position of the rotor.

11.6.3 When measured as described in **11.6.2** the rotor contact resistance at any position of the rotor shall not exceed the value specified in the relevant specification.

11.6.4 The relevant specification shall specify:

a) current (if less than 1A), and

b) maximum value of the rotor contact resistance.

11.7 Temperature Coefficient

11.7.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**, and the rotor shall be set

to the following positions which shall be maintained throughout the test:

Type A	40 to 60 percent of the nominal maximum capacitance
Types B and C	60 to 80 percent of the nominal maximum capacitance

11.7.2 The capacitor shall be maintained at each of the following temperatures in turn:

a) $25 \pm 2°C$ (standard room temperature for testing),

b) Lower category temperature $^{+6}_{-0}$ °C,

c) $25 \pm 2°C$,

d) Upper category temperature $^{+0}_{-4}$ °C, and

e) $25 \pm 2°C$.

(a), (c) and (e) shall be within 4°C of each other.

The cycle shall be carried out once, temperature shocks shall be avoided.

11.7.3 Capacitance measurements shall be made at each of the temperatures specified in **11.7.2** after the capacitor has reached thermal stability and with the same electrical conditions for all measurements.

The condition of thermal stability shall be judged to have been reached when two readings of capacitance taken at an interval of 5 minutes do not differ by an amount greater than that which can be attributed to the measuring apparatus.

Extreme caution shall be taken in maintaining constant capacitance between leads from test equipment to capacitors for all measurements.

The temperature of the chamber at the time of each capacitance measurement shall be recorded. The measurement of temperature shall be accurate to 0·5°C.

11.7.4 The average temperature coefficient in parts per million per degree Celsius based on the largest capacitance change obtained over the complete cycle is calculated from the following formula:

$$\frac{\Delta C}{C\,\Delta t} \times 10^6$$

where

C = the capacitance value at standard room temperature for testing [**11.7.2**(a)] for the temperature coefficient at lower category temperature [**11.7.2**(b)] and the capacitance value at 25°C [**11.7.2**(c)] for the temperature coefficient at upper category temperature [**11.7.2**(d)],

$\triangle C$ = the difference between C and the capacitance value at the test temperature, and

$\triangle t$ = the difference in degrees Celsius between the test temperature and temperature mentioned in **11.7.2**(a) or **11.7.2**(c) as appropriate.

11.7.5 The temperature coefficient determined as described in **11.7.4** shall be within the limits specified in the relevant specification.

11.7.6 The relevant specification shall specify:

a) the method of mounting, and

b) the limits of temperature coefficient.

11.8 Capacitance Drift

11.8.1 Capacitance drift is the difference between the capacitance values obtained at the temperatures mentioned in **11.7.2**(a) and **11.7.2**(c). This difference is expressed as a percentage of the capacitance value measured at temperature mentioned in **11.7.2**(a).

11.8.2 The capacitance drift shall be within the limits specified in the relevant specification.

12. MECHANICAL TESTS

12.1 Visual Examination — The condition, workmanship, marking and finish shall be satisfactory as determined by visual examination.

12.2 Dimensions — The dimensions and the effective angle of rotation shall conform to those specified in the relevant specification.

12.3 Operating Torque

12.3.1 The capacitor shall be mounted as described in the relevant specification using one of the methods specified in **8.6** with the rotor shaft horizontal.

12.3.2 The torque required to turn the actuating device (including the starting torque) to any angle in both directions, that is, clockwise and anticlockwise shall be measured. For preset capacitors with deliberately increased starting torque, this torque shall be separately measured.

12.3.3 The operating torque shall be within the limits specified in the relevant specification.

12.3.4 The relevant specification shall specify:

a) the method of mounting;

b) the limits of the operating torque; and

c) for preset capacitor with deliberately increased starting torque, the limits of this torque.

12.4 Locking

12.4.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6** and the rotor set at a position equivalent to 40 to 60 percent of the nominal maximum capacitance and the capacitance measured as specified in **11.1.1**.

12.4.2 The actuating device shall then be locked by the application of the torque specified in the relevant specification to the locking device and the capacitance shall again be measured.

12.4.3 The change of capacitance shall not exceed the value specified in the relevant specification.

12.4.4 The torque specified in the relevant specification shall then be applied in a clockwise direction to the locked actuating device and the capacitance shall again be measured.

12.4.5 The torque specified in the relevant specification shall then be applied in an anticlockwise direction to the locked actuating device and the capacitance shall again be measured.

12.4.6 The capacitance change after each application of the torque compared with the value measured after locking the actuating device shall not exceed the value specified in the relevant specification.

12.4.7 The relevant specification shall specify:

a) the method of mounting,
b) the locking torque,
c) limit of capacitance change after locking,
d) torque applied to the locked actuating device, and
e) limit of capacitance change after application of torque to the locked actuating device.

12.5 Locking-Torque Proof

12.5.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

12.5.2 A torque equal to twice the locking torque specified in **12.4.2** shall be applied to the locking device. There shall be no loosening of parts.

12.5.3 The relevant specification shall specify the method of mounting.

12.6 End-Stop Torque

12.6.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

12.6.2 The rotor shall be set against one end stop and the actuating device shall be subjected to the torque specified in the relevant specification for a period of 10 seconds. The test shall be repeated with the rotor set against the other end stop.

12.6.3 There shall be no mechanical damage as determined by visual examination.

12.6.4 The relevant specification shall specify:

a) the method of mounting, and

b) applied torque.

12.7 Thrust and Pull (Axial)

12.7.1 *Thrust* — The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**. If a rotor locking device is provided it shall be removed or left free. The rotor shall be set at the following position which shall be maintained throughout the test:

Type A	40 to 60 percent of the nominal, maximum capacitance
Types B and C	60 to 80 percent of the nominal maximum capacitance

12.7.2 The capacitance shall then be measured as specified in **11.1.1.**

12.7.3 The application of the axial thrust as specified in the relevant specification shall be applied to the operating end of the actuating device. Care shall be taken to ensure that the specified loads are not exceeded.

12.7.4 Under these conditions the capacitance shall be measured as specified in **11.1.1.**

12.7.5 The change of capacitance compared with that measured before the test shall be not greater than the value specified in the relevant specification.

12.7.6 The relevant specification shall specify:

a) the method of mounting,

b) the thrust to be applied, and

c) the limit of the capacitance change.

12.7.7 *Maximum Permissible Thrust* — The thrust specified in the relevant specification shall be applied to the operating end of the actuating device for 10 seconds. There shall be no damage as determined by visual examination.

12.7.8 The relevant specification shall specify the permissible thrust.

12.7.9 *Maximum Permissible Pull* — The pull specified in the relevant specification shall be applied to the operating end of the actuating device for 10 seconds. There shall be no damage as determined by visual examination.

12.7.10 The relevant specification shall specify the permissible pull.

12.8 Side Thrust

12.8.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**. The rotor shall be set at the following position which shall be maintained throughout the test:

Type A	40 to 60 percent of the nominal maximum capacitance
Types B and C	60 to 80 percent of the nominal maximum capacitance

12.8.2 The capacitance shall be measured as specified in **11.1.1**.

12.8.3 The thrust specified in the relevant specification shall be applied at the operating end of the actuating device at right angles to its axis at a point 10 mm, unless otherwise specified, from the outer face of the bearing for 10 seconds.

12.8.4 Under such conditions capacitance shall be measured as specified in **11.1.1**.

12.8.5 The change of capacitance compared with the value measured before the application of the thrust shall not exceed the value specified in the relevant specification.

12.8.6 The thrust shall then be applied in turn to points 90°, 180° and 270° circumferentially from the original point of application for a period of 10 seconds and the capacitance measured on each application of the thrust.

12.8.7 The change of capacitance compared with the initial measurement shall not exceed the value specified in the relevant specification.

12.8.8 The relevant specification shall specify:

a) the method of mounting,
b) the applied thrust,
c) point of application (if other than 10 mm), and
d) maximum permitted capacitance change.

12.9 Robustness of Terminations

12.9.1 *Tensile* — The terminations shall be subjected to this test in accordance with **7.19.1** of IS : 589-1961* using the degree of severity specified in the relevant specification.

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12.9.1.1 Screw terminations shall in addition be subjected to a thrust as specified in the relevant specification. There shall be no damage to the terminations or the capacitor.

12.9.2 *Bending* — Terminations designed to be bent shall be subjected to this test in accordance with **7.19.2** of IS : 589-1961*. The number of bends shall be as specified in the relevant specification.

12.9.2.1 There shall be no damage to the terminations or the capacitor.

12.9.3 *Torsion* — Screw termination shall be subjected to this test in accordance with **7.19.4** of IS : 589-1961*. There shall be no damage to the terminations or the capacitor.

12.10 Backlash

12.10.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

12.10.2 Commencing at the minimum capacitance position, the rotor shall be rotated to a position representing approximately 50 percent of the total capacitance swing and the capacitance (C_b) measured at this position.

12.10.3 The rotor shall then be rotated with a smooth continuous movement to a near maximum position and returned to the measuring point as above with a setting accuracy as since in **11.1**(b) and the capacitance measured again (C_c).

12.10.4 The backlash based on the difference in the capacitance values measured as above is an absolute value calculated from the following formula:

$$d = \frac{(C_b - C_c)}{C_b} \times 10^6$$

where

d = backlash in parts per million, and

C_b and C_c = capacitance values measured as above.

12.10.5 The backlash determined as specified shall be within the limits specified in the relevant specification.

12.10.6 The relevant specification shall specify:

a) method of mounting, and

b) the limits of the backlash.

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12.11 Soldering

12.11.1 That part of each termination designed to be soldered shall be subjected to this in accordance with **7.18.2** of IS : 589-1961*.

12.11.2 On completion of the test there shall be no mechanical deterioration as determined by visual examination. Any additional requirements shall be specified in the relevant specification.

12.11.3 The relevant specification shall specify:

a) the appropriate procedure (solder bath or solder iron),

b) any deviation from the depth of immersion (solder bath method),

c) duration of application and wetting times and size of soldering iron (solder iron method),

d) period of recovery,

e) temperature for resistance to heat test if other than 350°C, and

f) additional requirements (when necessary).

12.12 Bump

12.12.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6** and the mounting plate shall be rigidly fixed to the bumping machine. The rotor shall be set at near-maximum capacitance but clear of end stops and adequately locked to prevent rotation but without restriction of other movements so that no stress is placed on any part of the capacitor.

12.12.2 A capacitor with a locking device shall be locked by the application of the torque specified in **12.4.2**. Preset capacitors intended to be locked shall be locked in the manner specified in the relevant specification.

12.12.3 The capacitance shall then be measured as specified in **11.1.1**.

12.12.4 The capacitor shall then be subjected to this test in accordance with **7.5.1** of IS : 589-1961* using the severity specified in the relevant specification.

12.12.5 At the conclusion of the test the capacitance shall again be measured and the change of capacitance compared with that measured in **12.12.3** shall not exceed that specified in the relevant specification.

12.12.6 The capacitors shall then be removed from the mounting plate and the rotor locking removed. The capacitors shall be visually examined, there shall be no mechanical damage.

12.12.7 Sealed capacitors shall be subjected to the test of **12.16.5**. The rate of leakage of air shall not exceed that specified in the relevant specification.

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12.12.8 The relevant specification shall specify:

a) the method of mounting,

b) locking (for preset types),

c) severity of bump test,

d) maximum permissible change of capacitance, and

e) rate of leakage of air (sealed capacitors only).

12.13 Shock

12.13.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6** and the mounting plate shall be rigidly fixed to the shock machine. The rotor shall be set at near maximum capacitance but clear of end stops and adequately locked to prevent rotation but without restriction of other movements so that no stress is placed on any part of the capacitor.

12.13.2 A capacitor with a locking device shall be locked by the application of the torque specified in **12.4.2.** Preset capacitors shall be locked in the manner specified in the relevant specification.

12.13.3 The capacitance shall then be measured as specified in **11.1.1.**

12.13.4 The capacitor shall then be subjected to this test in accordance with **7.5.2** of IS : 589-1961* using the severity specified in the relevant specification.

12.13.5 At the conclusion of the test the capacitance shall again be measured and the change of capacitance compared with that measured earlier shall not exceed that specified in the relevant specification.

12.13.6 The capacitors shall then be removed from the mounting plate and the rotor locking removed. The capacitors shall be visually examined, there shall be no mechanical damage.

12.13.7 Sealed capacitors shall be subjected to **12.16.5.** The rate of leakage of air shall not exceed that specified in the relevant specification.

12.13.8 The relevant specification shall specify:

a) the method of mounting,

b) locking (for preset types),

c) severity of shock test,

d) maximum permissible change of capacitance, and

e) rate of leakage of air (sealed capacitors only).

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12.14 Vibration

12.14.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6** and the mounting plate shall be rigidly fixed to the vibration machine. The rotor shall be set at near maximum capacitance but clear of end stops and adequately locked to prevent rotation but without restriction of other movements so that no stress is placed on any part of the capacitor.

12.14.2 A capacitor with a locking device shall be locked by the application of the torque specified in **12.4.2**. Preset capacitors intended to be locked shall be locked in the manner specified in the relevant specification. The capacitance shall then be measured as specified in **11.1.1**.

12.14.3 The capacitor shall be subjected to this test in accordance with **7.6** of IS : 589-1961* at the severity specified in the relevant specification.

12.14.4 At the conclusion of the test the capacitance shall again be measured and the change of capacitance compared with that measured in **12.14.2** shall not exceed that specified in the relevant specification.

12.14.5 The capacitors shall then be removed from the mounting plate and the rotor locking removed. The capacitors shall be visually examined, there shall be no mechanical damage.

12.14.6 Sealed capacitors shall be subjected to **12.16.5**. The rate of leakage of air shall not exceed that specified in the relevant specification.

12.14.7 The relevant specification shall specify:

a) the method of mounting,

b) locking (for preset types),

c) severity of vibration test,

d) maximum permissible change of capacitance, and

e) rate of leakage of air (for sealed capacitors only).

12.15 Acceleration

12.15.1 The capacitor shall be mounted as specified in the relevant specification using one of the methods specified in **8.6** and the mounting plate shall be rigidly fixed to the acceleration machine. The rotor shall be set at near maximum capacitance but clear of end stops and adequately locked to prevent rotation but without restriction of other movements so that no stress is placed on any part of the capacitor.

12.15.2 A capacitor with a locking device shall be locked by the application of the torque specified in **12.4.2**. Preset capacitors shall be locked in the manner specified in the relevant specification.

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12.15.3 The capacitance shall then be measured as specified in **11.1.1.**

12.15.4 The capacitor shall then be subjected to this test in accordance with **7.7** of IS : 589-1961* using the severity specified in the relevant specification.

12.15.5 At the conclusion of the test the capacitance shall again be measured and change of capacitance compared with that measured earlier shall not exceed that specified in the relevant specification.

12.15.6 The capacitor shall then be removed from the mounting plate and the rotor locking removed. The capacitor shall be visually examined, there shall be no mechanical damage.

12.15.7 Sealed capacitor should be subjected to the test of **12.16.5.** The rate of leakage of air shall not exceed that specified in the relevant specification.

12.15.8 The relevant specification shall specify:

a) the method of mounting,
b) locking (for preset types),
c) severity of acceleration test,
d) maximum permissible change of capacitance, and
e) rate of leakage of air (for sealed capacitors only).

12.16 Sealing (Normal Conditioning)

12.16.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6.**

12.16.2 The capacitors shall be subjected to this test in accordance with **7.15** of IS : 589-1961* at the severity specified in the relevant specification.

12.16.3 The rate of leakage of air shall not exceed the value specified in the relevant specification.

12.16.4 The relevant specification shall specify:

a) the method of mounting,
b) the severity of the test, and
c) the permissible rate of leakage of air.

12.16.5 *Sealing (Extended Conditioning)*

12.16.5.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6.** The capacitors shall be subjected to this test in accordance with **7.15.3** of IS : 589-1961* at the severity specified in the relevant specification. The leakage of air across all seals shall not exceed the value specified in the relevant specification.

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12.16.5.2 The capacitors shall then be subjected to the mechanical endurance test of **16.1.1** under the atmospheric conditions for testing specified in **8.2** for the number of cycles specified in the relevant specification.

12.16.5.3 At the conclusion, the rate of leakage of air shall not exceed the value specified in **12.16.5.1**:

a) with end thrust and axial pull applied as in **12.7**, and

b) with side thrust applied as in **12.8**.

12.16.5.4 The capacitor shall then be subjected to dry heat in accordance with **7.2** of IS : 589-1961*. At the conclusion, and while still at the high temperature, the capacitors shall meet the requirements specified in **12.16.5.1**.

12.16.5.5 The capacitors shall then be subjected to cold test in accordance with **7.15.3.3** of IS : 589-1961*. At the conclusion and while still at the low temperature, the capacitors shall meet the requirements specified in **12.16.5.1**.

12.16.5.6 *For types where the actuating device protrudes from the capacitor* — After recovery and while the rotor is being operated as in **16.1.1** the capacitor shall meet the requirements specified in **12.16.5.1**.

12.16.5.7 The relevant specification shall specify:

a) the method of mounting,

b) severity of test **7.15.3.3** of IS : 589-1961*, and

c) permissible rate of leakage of air.

13. CLIMATIC TESTS

13.1 Climatic Sequence

13.1.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

13.1.2 *Dry Heat*

13.1.2.1 The capacitors shall be subjected to the dry heat test in accordance with **7.2** of IS : 589-1961* using the appropriate degree of severity.

13.1.2.2 While still at the specified high temperature and at the end of the period of high temperature, the operating torque shall be measured as in **12.3** and shall be within the limits specified in the relevant specification.

13.1.2.3 At the conclusion of the test, there shall be no mechanical deterioration as determined by visual examination.

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13.1.3 *Damp Heat (Accelerated) First Cycle*

13.1.3.1 The maximum capacitance shall be measured as specified in **11.1.1.1**.

13.1.3.2 The capacitors shall be subjected to the first cycle of damp heat (accelerated) test in accordance with **7.4** of IS : 589-1961*.

13.1.3.3 After recovery, the capacitance shall be subjected immediately to the cold test.

13.1.4 *Cold*

13.1.4.1 The capacitors shall be subjected to the cold test in accordance with **7.1** of IS : 589-1961* using the appropriate degree of severity.

13.1.4.2 While still at the specified low temperature and at the end of the period of low temperature, the starting torque shall be measured. The maximum value of the starting torque shall be as specified in the relevant specification. The operating torque shall be measured as in **12.3** after the actuating device has been turned once and shall be within the limits specified in the relevant specification.

13.1.4.3 At the conclusion of the test and after recovery, there shall be no mechanical deterioration as determined by visual examination.

13.1.5 *Low Air Pressure*

13.1.5.1 The capacitors shall be subjected to this test in accordance with **7.12** of IS : 589-1961* using the degree of severity specified in the relevant specification.

13.1.5.2 The relevant specification shall specify:

a) the duration of the test,

b) the temperature, and

c) the severity.

13.1.5.3 While still at the specified low pressure, the voltage proof test specified in **11.4** shall be applied using the peak value of the test voltage specified in the relevant specification.

13.1.5.4 There shall be no breakdown.

NOTE — For air dielectric capacitors preliminary sparking due to accumulation of dust may be ignored.

13.1.6 *Damp Heat (Accelerated) Remaining Cycles*

13.1.6.1 The capacitors shall be subjected to the remaining cycles of the damp heat (accelerated) test in accordance with **7.4** of IS : 589-1961*,

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the number of cycles being appropriate to the category as specified in the relevant specification.

13.1.6.2 *Final measurements* — After recovery, the capacitors shall be subjected to such of the following tests as are specified in the relevant specification:

a) Visual examination,
b) Tangent of loss angle,
c) Maximum capacitance,
d) Insulation resistance,
e) Rotor contact resistance,
f) Voltage proof,
g) Operating torque,
h) Solderability (only wetting), and
j) Sealing (for sealed capacitors only).

Tests (b), (c) and (d) shall be completed within 2 hours after recovery.

13.1.6.3 The relevant specification shall specify:

a) the method of mounting,
b) the degree of severity in each test,
c) operating torque at high and low temperatures,
d) duration of test and temperature for low air pressure test,
e) voltage to be applied at low air pressure, and
f) limits to be met in final measurements.

13.2 Damp Heat (Long Term Exposure)

13.2.1 The capacitors shall be mounted as prescribed in the relevant specification using one of the methods specified in **8.6**.

13.2.2 Type C capacitors fitted with a locking device shall be set at near maximum capacitance and locked by the application of the torque specified in **12.4.2**. Type C capacitors without a locking device shall be locked as specified in the relevant specification.

The following measurements shall be made:

a) Tangent of loss angle,
b) Insulation resistance, and
c) Maximum capacitance.

13.2.3 The capacitors shall be subjected to the damp heat (long term exposure) test in accordance with **7.3** of IS : 589-1961* using the degree of severity prescribed in the relevant specification.

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13.2.4 After recovery the capacitors shall be submitted to such of the following tests as specified in the relevant specification:

a) Visual examination,
b) Tangent of loss angle,
c) Maximum capacitance,
d) Insulation resistance,
e) Rotor contact resistance,
f) Voltage proof,
g) Operating torque,
h) Solderability, and
j) Sealing (sealed capacitors only).

Tests (b), (c) and (d) shall be completed within 2 hours after recovery.

13.2.5 The relevant specification shall specify:

a) the method of mounting,
b) the degree of severity, and
c) limits to be met in the final measurements.

13.3 Rapid Change of Temperature

13.3.1 The capacitor shall be mounted as prescribed in the relevant specification using one of the methods specified in **8.6** and the maximum capacitance measured.

13.3.2 The capacitor shall be subjected to rapid change of temperature test in accordance with **7.14** of IS : 589-1961* at the upper and lower category temperature specified in the relevant specification. The duration of each exposure to category temperatures to be 30 minutes.

13.3.3 After recovery, the capacitor shall be visually examined and there shall be no mechanical damage.

13.3.4 The change of capacitance from that measured before the commencement of this test shall not exceed the values specified in the relevant specification. The operating torque shall be within the limits stated in **12.3**. Sealed capacitors shall conform to the sealing test specified in **12.16**.

13.3.5 The relevant specification shall specify:

a) the method of mounting,
b) the limits of capacitance change, and
c) number of cycles.

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14. SALT MIST

14.1 The capacitors shall be subjected to this test in accordance with **7.10** of IS : 589-1961*. The duration of exposure shall be as specified in the relevant specification.

14.2 The capacitors shall be visually examined and there shall be no apparent damage and the markings shall be legible.

15. MOULD GROWTH

15.1 The capacitors shall be subjected to this test in accordance with **7.9** of IS : 589-1961*. The period of conditioning shall be as specified in the relevant specification.

16. ENDURANCE

16.1 Mechanical Endurance

16.1.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

16.1.2 Capacitors fitted with locking devices shall be locked and unlocked the number of times specified in the relevant specification using the torque specified in **12.5**.

16.1.3 Where because of the construction of the capacitor it is not possible to conduct tests for thrust and pull (axial) and side thrust, the maximum capacitance shall be measured as specified in **11.1.1.1**.

16.1.4 The capacitors shall then be subjected to the number of cycles of operation of the actuating device specified in the relevant specification.

16.1.5 A cycle refers to a clockwise and anti-clockwise rotation of the rotor over 90 ± 5 percent of the effective angle of rotation (that is from minimum to maximum and back to minimum capacitance but clear of end stops).

16.1.6 The rate of operation of the rotor throughout the test shall be as specified in the relevant specification.

16.1.7 At the completion of the test the specimens shall be allowed to obtain thermal stability under standard conditions for testing and then be submitted to such of the following tests as specified in the relevant specification:

a) Visual examination,

b) Thrust and pull (axial),

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c) Side thrust,
d) Maximum capacitance,
e) Operating torque,
f) Voltage proof,
g) Rotor contact resistance, and
h) Locking.

16.1.8 The relevant specification shall specify:
a) the method of mounting,
b) number of cycles of operation of the actuating device,
c) rate of operation of the actuating device,
d) final measurements, and
e) limits to be met in the final measurements.

16.2 Endurance (Electrical When Applicable)

16.2.1 The capacitors shall be mounted as specified in the relevant specification using one of the methods specified in **8.6**.

16.2.2 The capacitors shall then be subjected to the electrical endurance for the period and under the conditions specified in the relevant specification.

16.2.3 The measurements specified in the relevant specification shall then be made.

16.2.4 The relevant specification shall specify:
a) the method of mounting;
b) duration of the test (if other than 1 000 hours);
c) conditions of the test (that is voltage, temperature, etc); and
d) final measurements and limits.

17. CRACKLING — Under consideration.